Contribution of socio-economic benefits to economic efficiency of large-scale infrastructure projects

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Abstract

Methodology used for economic efficiency calculation of transport infrastructure is based on CBA method, which takes into account relatively accurate values of revenues and expenditures throughout the whole evaluated period. Since the significance of individual benefits among project is diverse, this paper aims at performing a detailed analysis of benefits (savings in travel and operating costs, savings in travel time costs, reduction in accident costs and savings in exogenous costs) and total agency costs, which are the most important inputs into calculation of economic efficiency ratio of the project – NPV, IRR and BCR. The analysis has been performed on the sample of 27 Czech large-scale transport infrastructure projects processed during 2013-2015 period. Regression analysis and correlation coefficient have been applied in order to determine the dependency between examined benefits and total agency costs. Research results have revealed that the largest share of the total project benefits is represented by savings in travel time costs and they have also reported the highest value of the correlation coefficient for this benefit in relation to total agency costs. Even though some benefits may acquire negative values, it means that the situation described by particular criterion has deteriorated and positive overall efficiency of the project is balanced by other significant benefit(s). It can be concluded that the overall benefits of the project show a significant positive correlation with the total agency costs, so even large-scale projects can be expected to deliver a reasonable amount of benefits to the society.

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Keywords: Transport infrastructure; CBA; Benefit; Correlation

1. Introduction

The area of the Czech Republic is considerably built-up. Due to its size and relatively short crossing time intervals, it has a character of a transit country where roads are burdened by relatively dense national as well as international passenger and freight transport. Authorities are trying to divert transit traffic from urban areas and lower class roads with the aim to create an interconnected highway transport system not only in the Czech Republic, but one related to the motorway networks of neighbouring countries. Thus concept design brings many positive effects that demonstrate the effectiveness of projects.

Evaluation of the effectiveness of projects is performed by the CBA (Cost Benefit Analysis) method, which works with the whole-society benefits evaluated in monetary units that are compared to their investment and operating costs. A really complex approach to evaluation of investment projects in the transport infrastructure on the basis of CBA can be found in the HDM-4 model (RSD CR, 2014). This model was developed during 1993-2000 period at the University of Birmingham with the financial support of the World Bank. HDM-4 model (Highway Development and Management) focuses on evaluation of investment projects in the area of transport infrastructure,
mainly projects of motorways. It represents a complex software tool for analyses of roads and motorways and investment decision-making process in this area. This method is applied in the Czech Republic using Czech economic parameters (unit price for all of solved variables).

The aim of this paper is to perform detailed analysis of four benefits: 1) savings in travel and operating costs, 2) savings in travel time costs, 3) reduction in accident costs and 4) savings in exogenous costs, in order to determine their relevance to the overall effectiveness of the project, which is also based on total agency costs (investment and operating).

The paper is structured as follows: firstly, review of the literature dealing with the issue of transport infrastructure projects, their impacts and effectiveness is presented. Then, methodology employed in the research is explained. Consequently, results are presented, discussed and compared with other studies where applicable. Finally, at the end of the paper, the main findings and outline of future research directions are outlined.

2. Literature Review

Infrastructure projects are very important for development of national economy. According to the current strategic documents, the emphasis of the EU economic policy is put on delivery of smart, sustainable and inclusive growth, innovation, research and development (Europe 2020). Economic growth and welfare depends on productive capital, infrastructure, human capital, knowledge, total factor productivity and quality of institutions (Guide to CBA, 2008). The Czech Republic together with other EU member states has entered the new programme period 2014-2020 with two main objectives (Investment for growth and jobs and European territorial cooperation).

Both objectives are in many aspects related to the transport infrastructure which represents the important prerequisite for the increase in the Czech Republic economy competitiveness as well as in competitiveness of particular regions. Even if its financing is considerably expensive, it is important at the same time because its technical condition is not good and the basic network of all types of transport has not been completed to the required extent yet. This condition can lead to gradual transformation of the Czech Republic into the periphery in the heart of the European continent (Transport sector strategy, 2013). Current profoundly insufficient funding into the road construction infrastructure results in developing enormous pressure on the economy and efficiency of its construction.

Therefore in current situation, it is necessary to pay more attention to the effective use of public resources. This should lead to introduction of particular arrangements. As the final consequence these steps should contribute to more transparent and more effective use of public resources. One of the basic objectives of the allocation of public resources is respecting the 3E principle (Economy, Effectiveness and Efficiency) in their whole life cycle. Economy refers to efforts to minimalize especially financial resources. In the context of effectiveness criteria, the ability to produce desired benefit is required. Efficiency indicates the use of such resources, which enable to achieve maximum volume and quality of products (Ochrana, 2010).

Economic impacts of land use and transport projects are potentially diverse. Economic impacts are usually grouped into (a) direct economic benefits, i.e. economic costs and benefits directly related to the project, where travel-cost savings form typically the most important (user) benefit category for infrastructure projects, and (b) indirect economic benefits, the (wider) economic effects not directly related to the project but resulting from the direct impacts, e.g. productivity gains of firms and distributional effects (Karst & Wee 2004). Among socio-economic impacts of transport projects are also included environmental impacts e.g. pollution or noise (Thanos et al. 2011), (Browne 2011) benefits to the natural habitat (Mancebo Quintana et al. 2010), visual intrusion, health impacts (Oxman et al. 2009), settlement cohesion, accessibility, land use planning, agglomeration, labour displacement and habitat fragmentation and equity (Thomopoulos & Grant-Muller, 2013), (Santos & al 2010).

Moreover improved transport infrastructure, particularly in the case of road and land transport, presumably leads to reduced transport costs. Road capacity improvements (such as more lanes, improved reliability, higher quality road surfacing, improved safety through more and wider lanes and improved signalization) reduce fuel consumption, wear and tear and transit time of traffic, accidents (Elvik, 2010). Such vast transport infrastructure investments have definitely impact on both the costs and quality of tourist experience (Khadaroo & Seetanah 2008).
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The need to use multi-criteria analysis and/or CBA for transport infrastructure projects evaluation is stressed by many authors (Deluka-Tiblijaš et al. 2013; Šelih et al. 2008; Stevens 2004; Gühnemann et al. 2012; Mackie et al. 2014, Hyard 2012, Jones et al. 2014 or Damard & Roy 2009). In case of the Czech Republic, the economic valuation of large-scale projects and megaprojects in transport infrastructure is based on principles of CBA and on the Implementing Guidelines for Evaluating the Efficiency of Road and Highways Construction in Investment objectives, issued by Ministry of Transport of the Czech Republic (RSD CR, 2014). The main criteria for evaluating the efficiency are the net present value (NPV), internal rate of return (IRR) and the benefit-cost ratio (BCR). The inputs for calculation are relevant socio-economic benefits and costs, in the Czech methodology the socio-economic benefits are savings in travel and operating costs, in travel time costs, reduction in accident costs and savings in exogenous costs.

As the studies of other authors show e.g. Parker (2012), Salling (2009), there are differences between the significance of individual benefits. This article thus contributes by the carried out analysis of the set of transport infrastructure projects to expanding knowledge in the area of evaluation of efficiency of transport infrastructure projects, in particular in the relation to achieving partial benefits corresponding to the project.

3. Methodology

The evaluation of economic efficiency of large-scale infrastructure projects in the Czech Republic is performed on the basis of instructions of Road and Motorway Directorate of the Czech Republic (RSD CR, 2014). These instructions solve possible appreciation of further benefits and costs in connection to the evaluated infrastructure in the Czech Republic. The cost model for the formation of cash flows create the following items of total agency costs (cost of construction and reconstruction and cost of maintenance and repairs of transport routes); travel and operating costs (fuels, lubricants, tire wear, repair and maintenance of vehicles and other expenses, trucks - crew wages, insurance, depreciation, overhead, valuation of time passengers and time value of carriage of goods); loss caused by traffic accidents and exogenous costs (loss from traffic noise; loss from motor vehicle exhaust gases).

The net cash flow (NCF) for calculating the valuation ratio (NPV, IRR, BCR) is based on information about present state and future development in traffic for zero and investment variant. Zero variant represents the variant “without the project”, investment variant supposes realisation of the valuated project. For both CF it is possible to know information about the traffic flow, its intensity, its structure and changes due to the project realisation. The NCF for evaluation criteria NPV, IRR and BCR are calculated as differential economic CF of both variants, e.g. without taxes (especially VAT or excise duty) and without cost reserves. In the last year of the evaluated period, residual value of the new investment is added as a positive cash flow. The evaluated period always includes the construction period and 30 years of project operation.

Current research has examined 27 large-scale transport infrastructure projects which investment intentions were assessed during 2013-2015 period in the area of the Czech Republic. Economic data was identified in the pre-investment phase of the project life cycle – on the business plan level, the model works with present values of these ones, for discounting calculation, a 5.5% discount rate was used (this value is uniform for the evaluation of transport infrastructure projects and is required by methodological guideline of RSD).

The results of empirical part of the research were processed in the following steps. Firstly, linear regression analysis was performed in order to determine the relationship between particular variable and the regressor (total agency costs). Initially, the dependence of total benefits was investigated, then that of individual benefits. Regression analysis has the potential to express the relationship between examined variables, while the slope of regress curves may describe the significance of the benefits with respect to the total project.

Secondly, the correlation analysis was carried out in order to determine the existence of dependence between variables as well as its tightness (the intensity level of dependence is expressed by Pearson’s correlation coefficient).
Finally, proportional representation of individual benefits to the overall effectiveness of the project can be seen in a bar chart. This allows not only to clearly identify the contribution of benefits, but also the potential occurrence of negative values.

4. Results and Discussion

4.1. Characteristics of research sample

The presented research deals with the large-scale projects and megaprojects of transport infrastructure, roads and highways in the Czech Republic. The total agency costs of these projects (investment and operating costs during 30-year operational period) are expressed in billion CZK.

From the substantive point of view, it deals with the projects of cities and villages bypasses, relocations of existing communications or new constructions of directionally divided expressways. City bypasses are built in the areas where there are adverse conditions both from the point of view of environmental burden, deterioration in comfort of transport and living conditions of the city inhabitants and from the point of view of significant time and economic loss of through traffic due to slow passage through the built-up areas with a number of remotely controlled traffic lights and pedestrian crossings.

Relocations of already existing communications result from substandard parameters of already existing direction and height solutions as well as the width ones. Due to a frequent passage through town residential areas, transport endangers also the residents’ safety and by noise and fumes it affects their health. New constructions of directionally divided expressways with the central dividing strip move themselves to higher category of roads with more convenient technical parameters.

All projects have reported positive value of NPV at 5.5% discount rate, average IRR was 10.83% and BCR at 1.95.

4.2. Regression analysis

All researched projects were evaluated on the basis of instructions of Road and Motorway Directorate of the Czech Republic (RSD CR, 2014). As the first step, regression analysis of the relationship between the total benefits and the current value of costs represented by total agency costs, was carried out. The resulting regression linear function is as follows:

\[ TBP = -2,718.4872 + 2.302 \times PVoTOC \]

where TBP represents total benefits of the project, PVoTOC represents present value of total agency costs as can be seen in Fig. 1. From the presented figure it can be seen that most of the projects report comparable relationship between the examined variables but the graph recorded higher deviations in 6 projects. This was the reason for further analysis of the behaviour of individual benefits and which of them influence this feature. Analysis of relationship between individual benefits and total project costs can be seen in Fig. 2. From the graphic display of the relationship it clearly results that the total benefits are to the biggest extent influenced by savings in travel time costs. Most of the values of researched projects are plotted on regression lines which run through individual points. Projects marked by red points in Fig. 2 top right represent two variants of project solution while these variants do not differ significantly both in the total costs and the benefits. This project deals with modernization of highway. Therefore it generates significantly higher savings in travel and operating costs compared to other researched projects.
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Figure 1. Relationship between total benefits and the current value of total agency costs (in billions. CZK*)

*Exchange rate: 1 € is on average 28 CZK
4.3. Correlation analysis

Since it is essential to investigate not only the dependence of individual variables but also tightness of their mutual relationship, correlation analysis using Pearson correlation coefficient was carried out. Tab. 1 shows the values of correlation coefficients of individual benefits as well as total benefits in relation to total agency costs.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value of correlation coefficient related to present value of total agency costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Benefits of Projects</td>
<td>0.952774</td>
</tr>
<tr>
<td>Savings in Travel and Operating Costs</td>
<td>0.762697</td>
</tr>
<tr>
<td>Savings in Travel Time Costs</td>
<td>0.924116</td>
</tr>
<tr>
<td>Reduction in Accident Costs</td>
<td>0.896545</td>
</tr>
<tr>
<td>Savings in Exogenous Costs</td>
<td>0.719422</td>
</tr>
</tbody>
</table>

Extremely tight positive linear relationship \( (r>0.9) \) was found in relation to present value of total agency costs in total project benefits \( (r = 0.952774) \) and in savings in travel time costs \( (r = 0.924116) \). However, also for all other partial benefits it is possible to identify strong positive relationship because the \( r \) values range within the \( (0.7 – 0.9) \) interval.

**Discussion**

Within the CBA, traditionally the travel-time savings represent a dominant benefit category for the users – consumers and firms (Karst & Wee, 2004). In connection to the significance of individual benefits, Parker (2012) presents the sources of benefits and their relative shares for several types of projects (public transport infrastructure projects, motorway construction, seal extensions, pavement smoothing, new and improved cycling networks, bridge renewals and others). Public transport infrastructure projects indicate as the main benefits travel time savings (about 85%) and decrease in accidents (about 15%). Projects of motorway construction possess the main benefits also in travel time savings (about 80%), in accidents (about 8%) and decrease in traffic congestion (about 12%). Also Salling (2009), Börjesson, Fosgerau & Algers (2012), Persson & Song (2010), Priemus & et al. (2008) state that the largest contributors to direct benefits from any transport project are the travel time savings.
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For clarity and better comparability, the results of this research are presented in the form of a bar chart (Fig. 3) showing the relative shares of individual benefits in individual projects.

Fig. 3 clearly shows dominant benefits in the item savings in travel time costs. Another unexpected output of the diagram is negative values of some benefits which indicate the fact that the observed factor deteriorated due to the project realisation. Projects 1, 14, 15, 17 and 26 report negative values in the area of saving in travel and operating costs, projects 10 and 25 report negative values in reduction in accident costs item.

Projects 10 and 25 are projects dealing with the construction of city bypasses and diversion of heavy traffic from the city streets. It suggests as the solution that in the residential areas there are accidents of minor severity compared to motorways and communication of higher classes where, as can be seen from statistics, take place more serious accidents which affect not only possession but also human health and lives. Average accident rate is included in the calculation.

Projects 1, 14, 15, 17 and 26 are projects which enable substantial speeding of the transport stream during relatively short arrival distances; in most cases it represents increase in the average speed from 90 km/hour to 130 km/hour. In higher speed, the costs connected to the use of vehicles rise (fuel consumption, tire wear off, spare parts etc.). The total benefit of these projects is based mainly on the transport time savings.

On the basis of the data presented in Tab.1, Fig. 2 and 3, it clearly shows that the most important share of the project benefits is represented by savings in travel time cost. The interval within these values fall is relatively narrow and the value of variability coefficient is relatively low. In contrast savings in travel and operating costs report high level of variability which rather results from the focus of the projects as well as savings in exogenous costs.

The results obtained can be argued that the travel time saving benefits are of relative share of about 77%. Since this benefit has been identified as the most significant, the results of this study support arguments and findings of similar types of research, for example by Karst & Wee (2004), Parker (2012) or Salling (2009).

Conclusion

This paper focused on the analysis of socio-economic benefits which created positive CF in the evaluation of large-scale transport infrastructure projects according to the Czech methodology. A major concern has been to determine how the particular benefits (savings in travel and operating costs, savings in travel time costs, reduction in accident costs and savings in exogenous costs) influence the total amount of benefits and whether it is possible to find the dependency between them and total agency costs.

The model has demonstrated that the “savings in travel time costs” are most important for evaluating projects and show the greatest dependence on total agency costs. Furthermore, extremely tight positive linear correlation between the value of total benefits and total agency costs has been proved. Thus, it can be concluded, that implementation of large-scale infrastructure project is closely linked to the achievement of reasonably high benefits which justifies their further planning and execution.

Finally, it should be said that every project of transport infrastructure is unique, economic outcomes are dependent mainly on its technical characteristics such prospective traffic intensity (number of vehicles / 24 hours) or the construction of a number of buildings that can be divided according to the purpose into road construction earthworks, bridges, flyovers and tunnels. Therefore, further research should address the correlations of benefits and technical characteristics of the projects.

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References


